GFDL Contribution to the September 2023 Sea Ice Outloook: July Report

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Note: This is an experimental prediction and is not an official NOAA forecast

1 Core sea ice outlook requirements

1. *Name of Contributor or name of Contributing Organization and associated contributors as you would like your contribution to be labeled in the report (e.g., Smith, or ARCUS (Wiggins et al.)).

   GFDL/NOAA, Bushuk et al.

   1b. (Optional but helpful for us): Primary contact if other than lead author; name and organization for all contributors; total number of people who may have contributed to your Outlook, even if not included on the author list.

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2. * Contributions submitted by a person or group not affiliated with a research organization, please self-identify here:
   ___Yes, this contribution is from "Citizen Scientists."

3. * Do you want your contribution to be included in subsequent reports in the 2023 season?

   ___Yes, use this contribution for all of the 2023 SIO reports (this contribution will be superseded if you submit a later one).
   __X_ No, I/we plan to submit separate contributions for subsequent reports.
   ___ No, I only want to participate this time.

4. *"Executive summary" of your Outlook contribution: in a few sentences (using 300 words or less) describe how and why your contribution was formulated. To the extent possible, use non-technical language.

   Our July 1 prediction for the September-averaged Arctic sea-ice extent is 4.38 million km^2, with an uncertainty range of 4.13–4.69 million km^2. Our prediction is based on the GFDL-SPEAR_MED ensemble forecast system, which is a fully-coupled atmosphere-land-ocean-sea ice model initialized using a coupled data assimilation system. Our prediction is the bias-corrected ensemble mean, and the uncertainty range reflects the lowest and highest sea ice extents in the 30-member ensemble.

5. *Type of Outlook method:

   __**X dynamic model** ___statistical___heuristic ___mixed or other (specify)

6. *Dataset of initial Sea Ice Concentration (SIC) used (include name and date; e.g., "NASA Team, May 2020"):

   OISST SIC data is used to correct assimilated SST values under sea ice.

7. Dataset of initial Sea Ice Thickness (SIT) used (include name and date):

   No SIT data is explicitly used in our initialization procedure.

8. If you use a dynamical model, please specify:

   a) Model name: **GFDL-SPEAR_MED**

   b) Information about components, for example:

Component	Name	Initialization (e.g., describe Data Assimilation)
Atmosphere	**AM4**	**Nudged atmosphere and SST run**
Land	**LM4**	**Nudged atmosphere and SST run**
Ocean	**MOM6**	**EnKF coupled data assimilation**
Sea Ice	**SIS2**	**Nudged atmosphere and SST run**

   c) Number of ensemble members and how they are generated:

   30 ensemble members of ocean initial conditions are generated from GFDL's ensemble Kalman filter (EnKF) coupled data assimilation system, which covers the period from 1990 to present. The nudged run ensemble members are initialized in 1990 from the SPEAR_MED large ensemble of historical simulations, and these provide the sea ice, atmosphere, and land initial conditions.

   d) For models lacking an atmosphere or ocean component, please describe the forcing:

9. *Prediction of September pan-Arctic extent as monthly average in million square kilometers. (To be consistent with the validating sea ice extent index from NSIDC, if possible, please first compute the average sea ice concentration for the month and then compute the extent as the sum of cell areas $\geq$ 15%.)

   4.38 million km^2

10. *Short explanation of Outlook method (using 300 words or less). In addition, we encourage you to submit a more detailed Outlook, including discussions of uncertainties/probabilities, including any relevant figures, imagery, and references.

    Our forecast is based on the GFDL Seamless system for Prediction and EArth system Research (SPEAR_MED) model (Delworth et al., 2020), which is a coupled atmosphere-land-ocean-sea ice model. The ocean model is initialized from an Ensemble Kalman Filter coupled data assimilation system (SPEAR ECDA; Lu et al., 2020), which assimilates observational surface and subsurface ocean data. The sea ice, land, and atmosphere components are initialized from a nudged ensemble run of the coupled SPEAR_MED model, which is nudged towards 3-D temperature, wind, and humidity data from CFSR and SST data from OISST. The SST values under sea ice are adjusted to the freezing point of sea water using OISST sea ice concentration data. The performance of this

model in seasonal prediction of Arctic sea ice extent has been documented in Bushuk et al. (2022). For an evaluation of the model's September sea ice extent prediction skill from a July 1 initialization, see Section 2 below.

11. If available from your method for pan-Arctic extent prediction, please provide:

a) Uncertainty/probability estimate such as median, ranges, and/or standard deviations (specify what you are providing).

Our range of September sea ice extent predictions is 4.13–4.69 million km^2, with a median value of 4.38 million km^2 and a standard deviation of 0.13 million km^2.

b) Brief explanation/assessment of basis for the uncertainty estimate (1-2 sentences).

These statistics are computed using our 30 member prediction ensemble.

c) Brief description of any post processing you have done (1-2 sentences).

These forecasts are bias corrected based on a linear-regression adjustment using a suite of retrospective forecasts spanning 1992-2022.

2 Assessment of Arctic Sea-Ice Extent Predictions

2.1 Retrospective forecast skill from July 1 Initialization

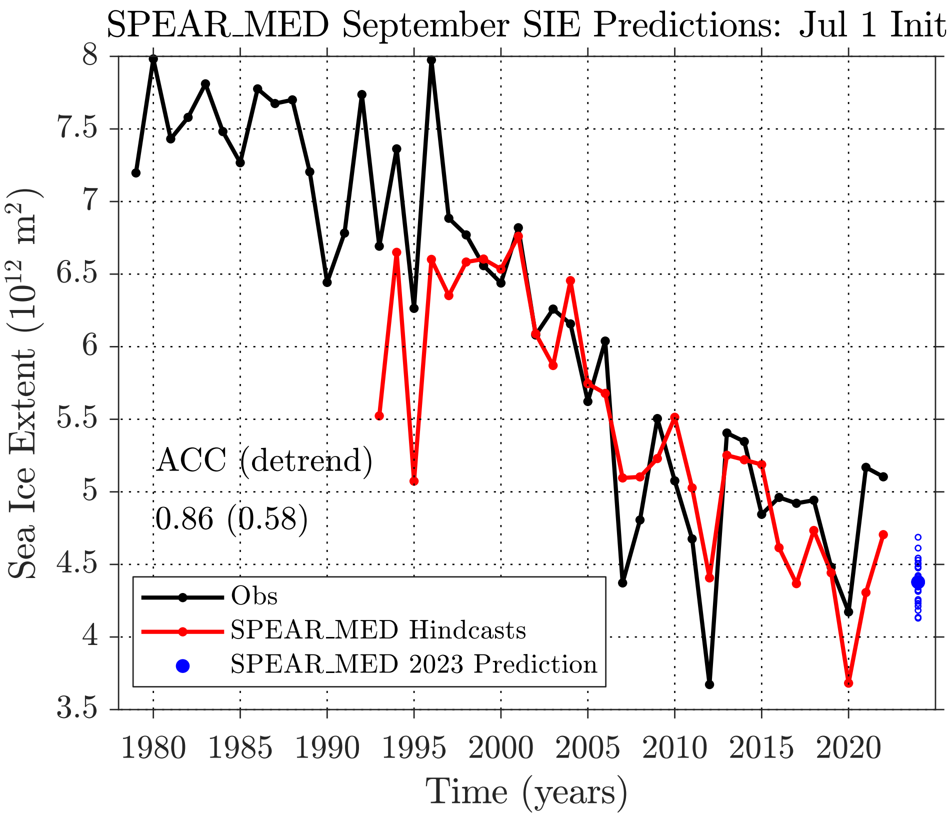

Figure 1: September pan-Arctic sea ice extent predictions from the GFDL-SPEAR_MED model initialized on July 1 (red dots) compared to NSIDC observations (black dots). The blue circles show the September 2023 predictions from the 30 ensemble members. The model predictions have been bias corrected via a linear-regression adjustment.

2.2 Monthly predictions from July 1: with bias correction

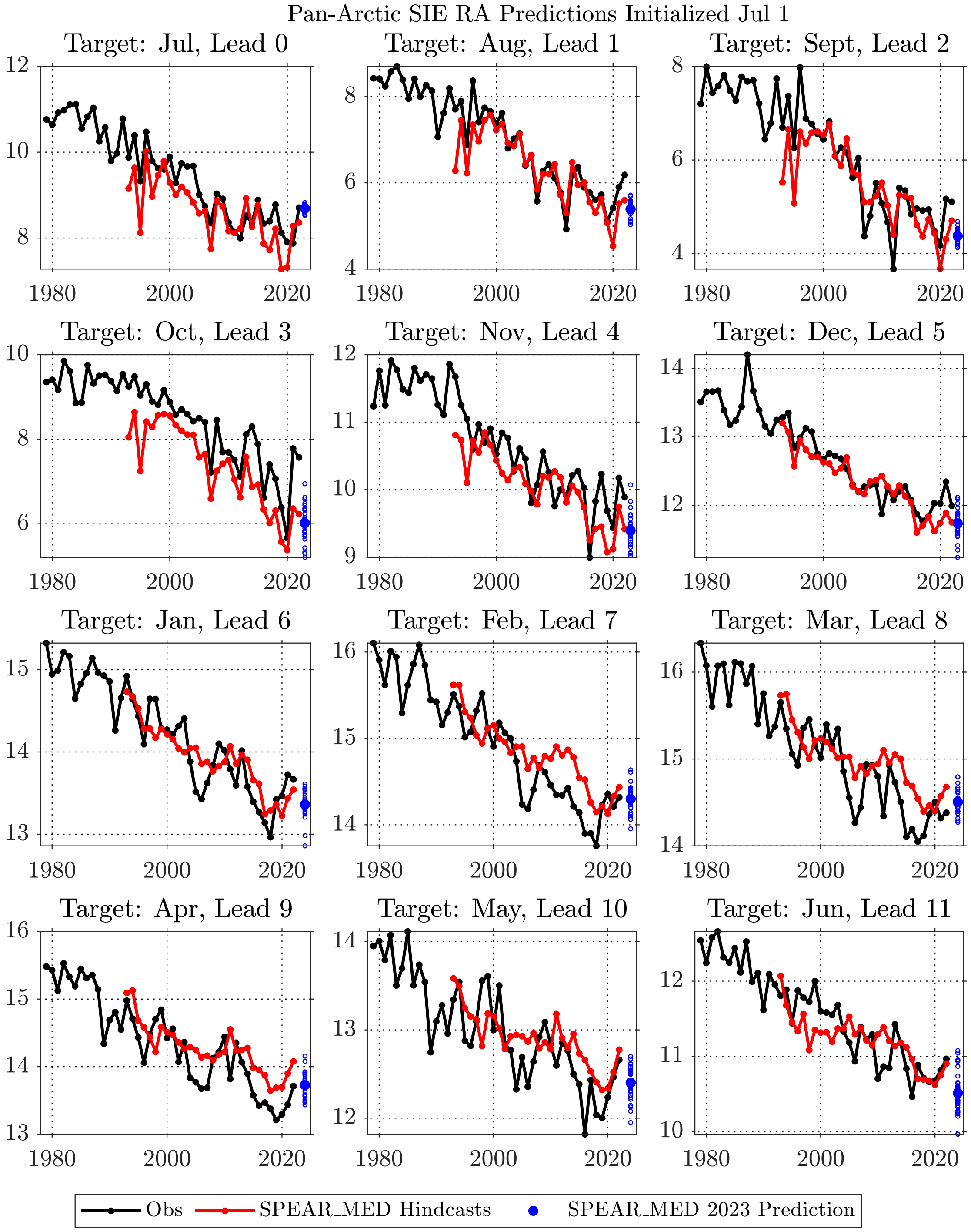

Figure 2: Monthly pan-Arctic sea ice extent predictions from the GFDL-SPEAR_MED model initialized on July 1 (red dots) compared to NSIDC observations (black dots). The blue circles show predictions from the 30 ensemble members. The model predictions have been bias corrected via a linear-regression adjustment.

2.3 Monthly predictions from July 1: no bias correction

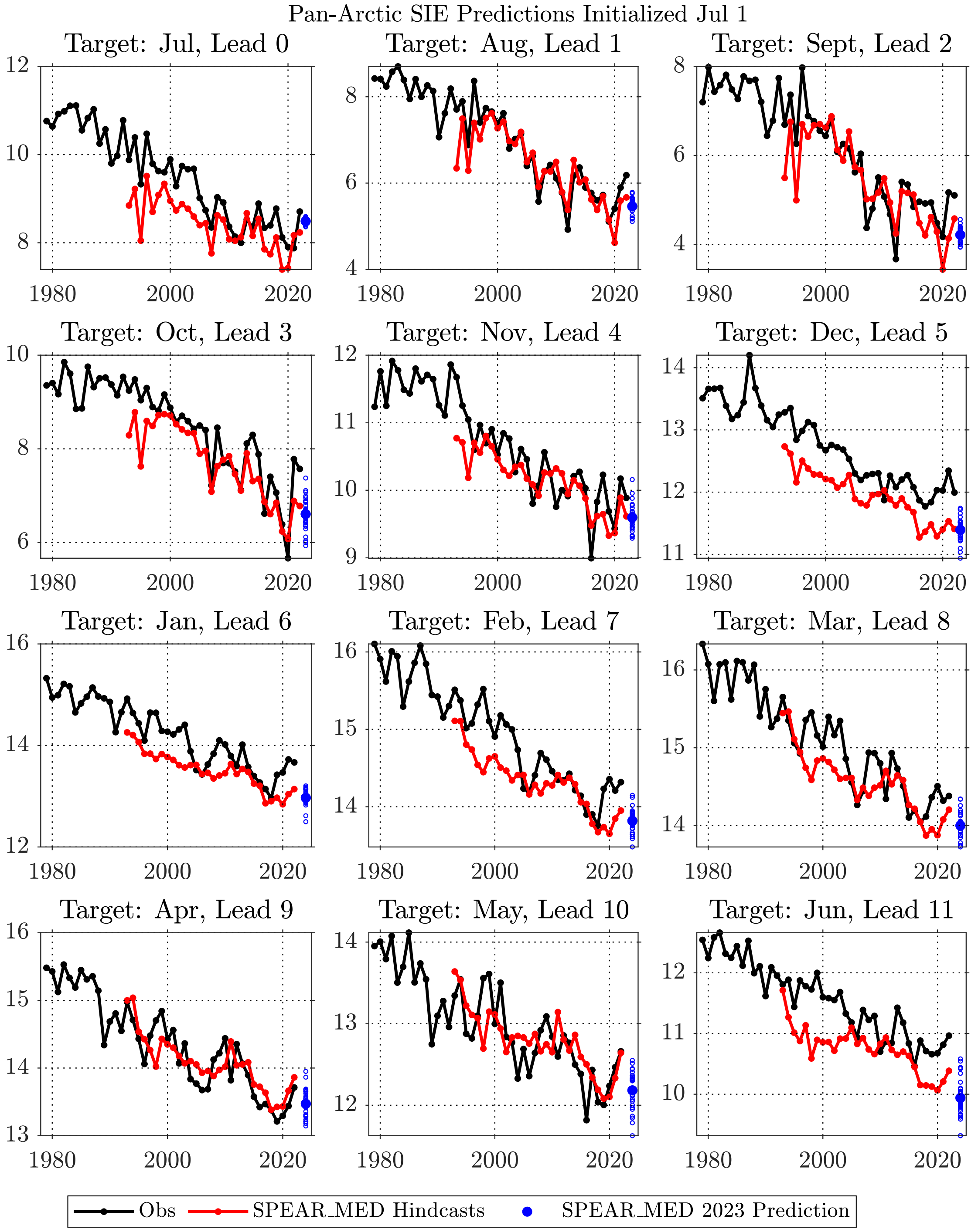

Figure 3: Monthly pan-Arctic sea ice extent predictions from the GFDL-SPEAR_MED model initialized on July 1 (red dots) compared to NSIDC observations (black dots). The blue circles show predictions from the 30 ensemble members. The model predictions have not been bias corrected.

3 Spatial Predictions: Predicted Sea Ice Concentration anomalies in different months

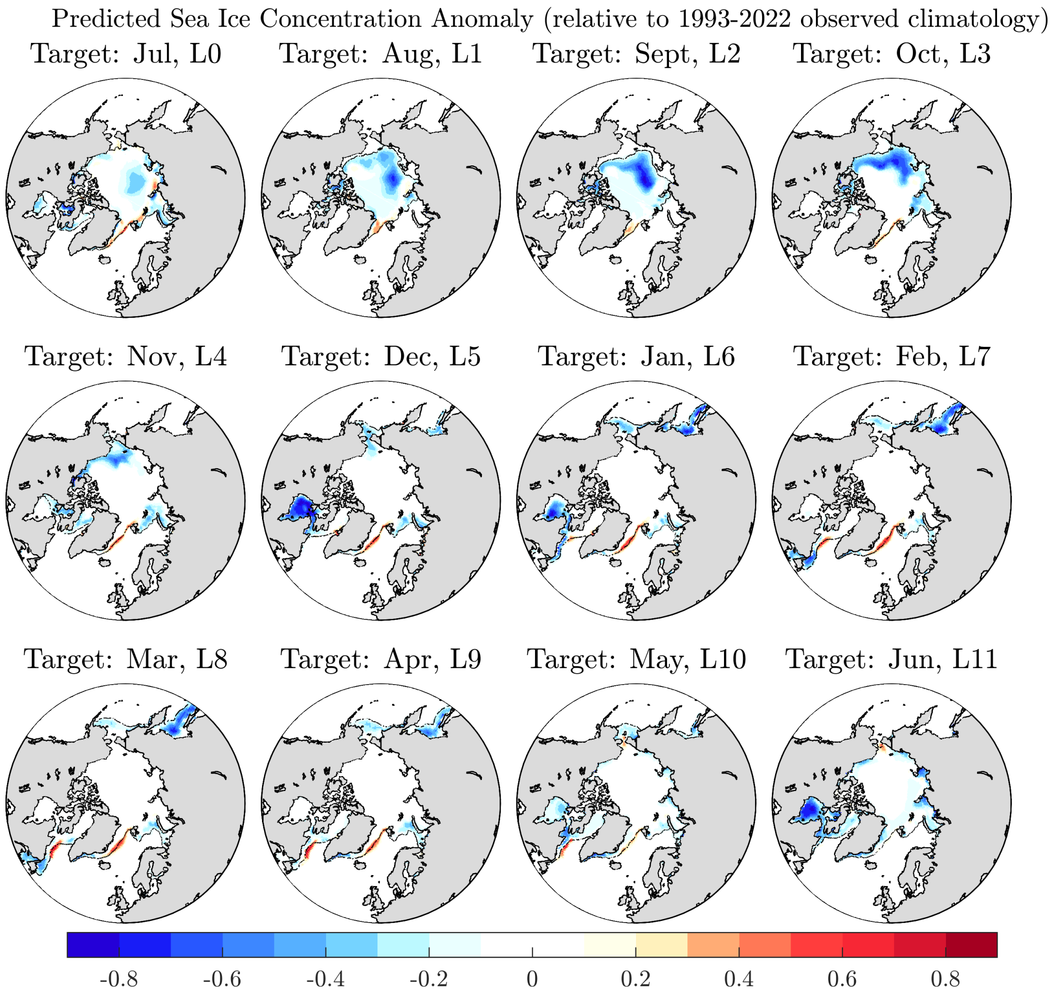

Figure 4: Monthly sea ice concentration anomaly predictions from the GFDL-SPEAR_MED model initialized on July 1. The anomalies are computed relative to the observed NSIDC NASA Team climatology over 1993–2022. The observed climatological sea ice edge position is shown in black. No bias correction has been applied.

4 Spatial Predictions: Predicted Sea Ice Concentration in different months

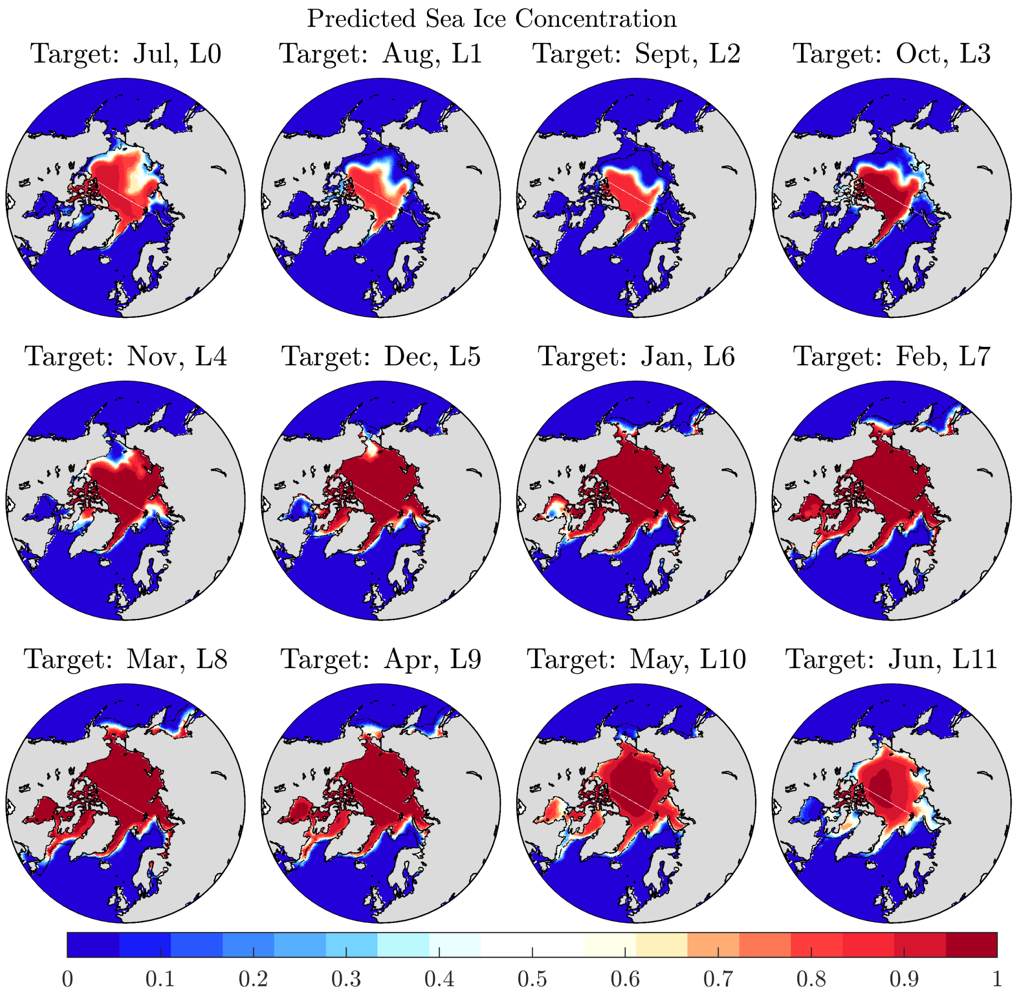

Figure 5: Monthly sea ice concentration predictions from the GFDL-SPEAR_MED model initialized on July 1. The observed climatological sea ice edge position is shown in black. No bias correction has been applied.

5 Alaskan Regional Sea Ice Extent Prediction

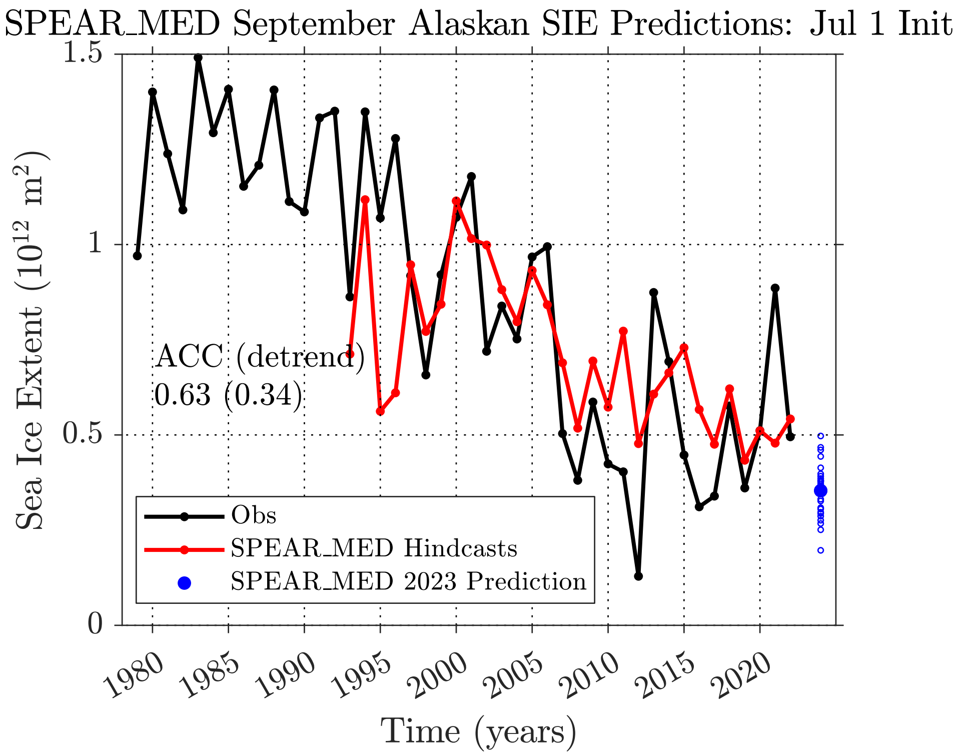

Figure 6: September Alaskan sea ice extent predictions from the GFDL-SPEAR_MED model initialized on July 1 (red dots) compared to NSIDC observations (black dots). The blue circles show the September 2023 predictions from the 30 ensemble members. The model predictions have been bias corrected via a linear-regression adjustment.

References

Bushuk, M., et al., 2022: Mechanisms of regional Arctic sea ice predictability in two dynamical seasonal forecast systems. *J. Climate*, **35 (13)**, 4207–4231.

Delworth, T. L., et al., 2020: SPEAR: The next generation GFDL modeling system for seasonal to multidecadal prediction and projection. *J. Adv. Model. Earth Syst.*, **12 (3)**, e2019MS001 895.

Lu, F., et al., 2020: GFDL's SPEAR seasonal prediction system: Initialization and ocean tendency adjustment (OTA) for coupled model predictions. *J. Adv. Model. Earth Syst.*, **12 (12)**, e2020MS002 149.